SeaTag™-RC: Remote Releasable Instrument Carrier for Marine Mammal Tagging

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LONG-TERM GOALS

The SeaTag-RC™ is going to be part of our SeaTag™ line of animal tags (Figure 1). Our goal for these tags is to offer a variety of options for positioning and data collection and to make retrieving and processing that data as seamless as possible. The entire line consists of the following in addition to the RC:

- SeaTag-GEO™, a small solar powered geolocation tag that uses earth's magnetic field strength along with light levels to calculate it's position.
- SeaTag-MOD™, a modular Argos satellite transmitting tag that will have optional payload sections along with a release mechanism based on the one developed for the SeaTag™-RC.
- SeaTag-SOL™, a lifetime animal tag with wireless networking along with a variety of sensors building on the positioning capabilities of the SeaTag-Geo™.
- SeaTag-CAM™, a solar powered camera running Linux that sends back images via Satellite using Argos by breaking the image into pieces and sending them over a period of a week.

Our plan is to develop the basic capabilities of these devices first and then add additional capabilities and tags after refining the core technology blocks. All of the tags besides the GEO, including our camera tag, will have the ability to be software upgraded to a mesh networking capability using their Zigbee RF modules. This kind of software upgrade will eventually allow for the Argos enabled tags to act as access points for other tags to get their data back to the scientists studying the animals they're on. This will probably first be implemented using SeaTag-CAM™ units placed around animal colonies as hotspots that aggregate animal data after it bounces down the beach from animal to animal. These cameras could then transmit this data via satellite or store it until the camera is retrieved and only transmit images.

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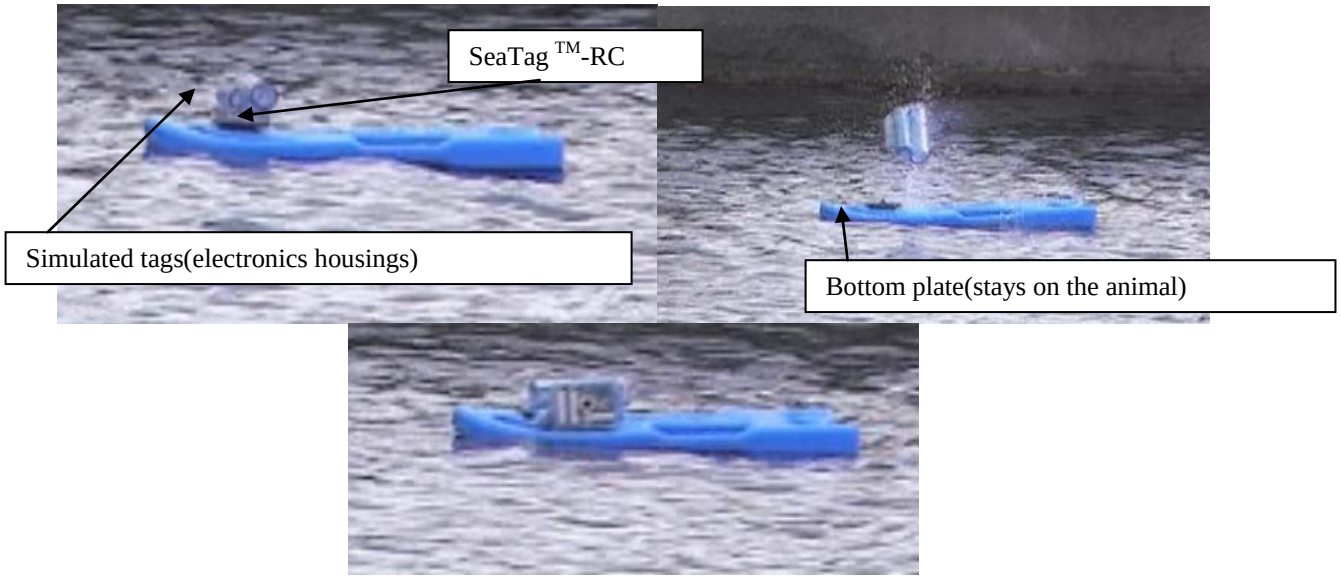

Figure 1. Video still frames of a SeaTag™-RC(SRC) with simulated tags attached popping off a kickboard in a phase I ocean test.

OBJECTIVES

Tagging any member of a group of animals may be difficult, but retrieving a device from a particular animal is much harder. The SeaTag Releasable Carrier (SeaTag™-RC) addresses this problem with a remote releasable instrument carrier that allows for reliable and on demand retrieval of equipment from an animal at short and long range. This capability will allow for a support craft to retrieve instruments from a specific cetacean or other animal as the opportunity arises and without a pre-programmed schedule.

To accomplish this task the SeaTag-RC uses a two plate design that is close to the size of a deck of cards. One side is a polycarbonate shell filled with epoxy that holds the electronics, and the other side is a laser cut piece of delrin that attaches to an animal. A plastic screw in the o-ring sealed center burn chamber attaches the two sides together and is surrounded by a small amount of propellant. Lastly, two set screws are used to keep the bottom plate from rotating and detaching. Triggering of the device is accomplished via a radio command which ignites the propellant on top of the trigger circuit board and pushes the two plates apart.

Other notable features of the device include batteries with a low-self discharge rate paired with a solar panel that recharges them, and a low power consumption microcontroller. The table below summarizes the various features of the device, work that has been performed, and areas that need improvement.

APPROACH

Our general approach is to go from concept to field tested prototype as quickly as possible so that we can then refine the prototype based the results of testing. This led the SeaTag-RC™ to be successfully tested in a harbor at the end of phase I using machined housing parts along with a PCB and accompanying hardware.

The key individuals involved in this project are as follows:

UCSC Personnel
Dan Costa, Ph.D.: Dan Costa is the supervisor of the project for UCSC (Figure 2). He will review the RRD test results and provide guidance for the engineering and refinement of the device.

Dan's research interests include The adaptations of marine mammals and seabirds to life in the marine environment, especially the movements, foraging ecology and energetics of pinnipeds and seabirds.

Dan's numerous publications are listed here:
http://bio.research.ucsc.edu/people/costa/people/costa.html

Figure 2. Dan Costa, Ph. D.

Samantha Simmons, Ph.D.: A post-doctoral researcher, Samantha will be in charge of developing the test plan and executing the translocation tests. Samantha will review RRD progress, and provide guidance based on UCSC's and her personal experience with marine mammal tagging. Her research interests revolve around trying to understand the foraging behavior of marine mammals (primarily pinnipeds) in relation to their oceanographic environment (Figure 3).

Samantha has published several papers, which are listed here:
http://bio.research.ucsc.edu/people/costa/people/simmons.html

Figure 3. Samantha Simmons, Ph.D.

Patrick Robinson: A Ph. D. student, Patrick Robinson's current research interest is exploring the navigation and search behaviors of the northern elephant seal (*Mirounga angustirostris*). Patrick is heavily involved in the UCSC marine mammal tagging program as part of his research, and will assist Samantha in the translocation tests and RRD performance evaluation (Figure 4).

Patrick has published several papers related to his work, which are listed here:
http://bio.research.ucsc.edu/people/costa/people/robinson.html

Figure 4. Patrick Robinson

Desert Star Systems Personnel
Marco Flagg (PI): Marco Flagg is the principal investigator on this project, and also the CEO of Desert Star Systems, LLC. Marco will take a guidance and advisory role, supporting project manager Matthew Crenshaw in project management and chief software engineer Jeff Roberts in acoustic communication and navigation technology while taking charge of electronic designs. His specialty and passion is field testing, an activity emphasized and heavily practiced at Desert Star as a powerful means to develop the innate know-how of what works or doesn't in the field. He deployed to Antarctica for two months in 2008 and 2009 each in support of a science team from Moss Landing Marine Labs. Besides his duties on an underwater robotics project and associated SCUBA diving under the ice, he used the opportunity for extreme environment testing of new Desert Star technologies including the Southstar™ positioning system, the FrogEye™ amphibious digital camera and the SeaTag™ animal tags / environmental micro observation stations.

Most of Desert Star's product line has originally been conceptualized by Marco Flagg, and he continues to design much of the electronics.

Marco Flagg has published numerous articles and presented at a number of conferences and committees in areas including underwater acoustics, digital camera design and computer design.

Figure 5. Marco Flagg

Excerpts of Bibliography:

- *The RangeNav™ Portable Underwater Tracking Range: A Review of the First Year of Operations.* Proceedings of Underwater Intervention 2008.

- *Boosting Field Intelligence Collection with the FrogEye™ Amphibious Digital Camera.* International Soldier Systems Conference, Boston, 2004

- *Acoustic Positioning for Manned Submersibles*. Proceedings of Underwater Intervention 2005

- *An Acoustic-transponder Tracking and Data Telemetry System for Monitoring Behaviors and Determining Real-time 3-D Underwater Locations from Large Marine Vertebrates.* Proceedings of the Forum on Wildlife Telemetry, Snowmass Village, Colorado 1997

- *Overview of single photon detector CCD night vision technology and relevant export controls.* Sensors and Instrumentation Technical Advisory Committee (SITAC) meeting, Washington, DC 27 October 2005 (Bureau of Industry and Security, Department of Commerce)

Matthew Crenshaw (Project Manager, Desert Star VP Engineering): Immediately after joining the company in 2008, Matthew contributed significantly to our NetTrack™ system, developing the embedded software for this specialized acoustic positioning system to measure the geometry of trawl nets. His engineering specialization is in Windows application design in particular using C#, where his latest contribution is the geo-positioning and other support software for our SeaTag™ animal tags / environmental micro observation stations. Beyond this specialization however, Matthew is a strong generalist in engineering and operations alike. Adept at mechanical modeling with Solidworks, the rapid implementation of electronic prototypes and an extensive knowledge of technological standards and methods, Matthews' expertise and hands-on knowledge has advanced multiple projects. A certified and experienced diver, Matthew along with Marco are our company's main field test team and will assure the delivery of realistic, field-capable technology under this project (Figure 6).

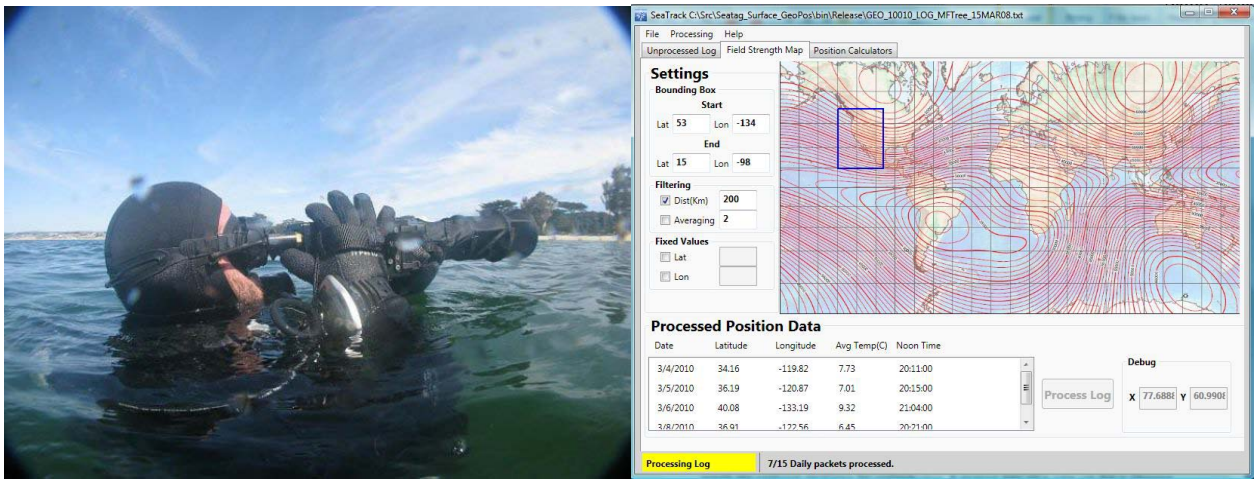

Figure 6. Matthew going for a swim with the FrogEye™ amphibious camera (left) along with his geo-positioning processing software for the SeaTag™ line of micro-observation stations(right).

Jeffrey Roberts: Jeffrey Roberts is our chief software engineer. Like most truly excellent programmers, he started programming at a very early age, specializing in particular in embedded systems designs and Linux systems, along with protocols, encryption and security measures. His contributions include driver software for the very unusual SeaTag docking station, which allows a micro tag to exchange data with a PC through a combination of light and RF signals. It is a method devised such that the micro tag did not require any additional electronics for communication: It receives data via a solar cell that is otherwise used for both energy harvesting and light measurements, while transmitting data by creating a RF signal simply by toggling a processor pin, then using the solar panel itself as the radio transmission antenna.

Thomas Gray, CFO: Thomas Gray joined Desert Star Systems in 2007, initially writing technical manuals. He quickly grew into the roles of customer support and marketing, and more recently also assuming the role of CFO in our company. Thomas has a thorough knowledge of our product line and is always available to discuss operations of our systems with the end-user.

WORK COMPLETED

Work categories	**Progress and successes**	**Problems to be worked on**
Release Mechanism(3.1)	A simple propellant release mechanism was selected due to the size constraints of the device. Its size prevented the use of a burn wire mechanism as used in our acoustic release (the ARC-1). The propellant mechanism has been very reliable in lab and ocean testing without causing major damage to the reusable portions of the device. David Bachelder from QuickBurst has agreed to sell refill kits on his website that will include a small amount of two part propellant to customers who	

	purchase this device. The customer would follow the directions in the refill kit to mix the oxidizer with the fuel and add the mixture to the burn chamber. A video showing the device triggering in the ocean is available here: http://www.youtube.com/watch?v=5fk8lpM45u8 or search for keyword "releasable instrument carrier" and click on the video titled "Marine Mammal Releasable Instrument Carrier End of Phase 1 Ocean Test".	
Housing Design(3.2)	Based on a conversation between Marco Flagg and seal researcher Randy Davis in Antarctica, and following tests in phase-1, a center-bolt design was selected. Davis also recommended that a shallow tray be used to attach the SeaTag-RC to the mammal and to "package any gaps," avoiding failures due to sand or water. His recommendations related to a similar study he performed with tags attached seals, and therefore was valuable. Taking Davis' advice into consideration we decided to make the base plate and releasable carrier plate separate and sturdy, in order to avoid any jamming issues. This dual plate design avoided the gap problems associated with having the electronics carrier fit into a base tray.	Tests need to be performed to see what the long-term effects of bio-fowling and animal behavior will be so we can adjust the propellant and housing accordingly. The buoyancy of the device should be increased through experimentation with syntactic foam.
Electronics design(3.3)	The first circuit board was designed and manufactured. The electronics sustain themselves through the solar panel and battery pack along with the microcontroller that puts the device into a "sleep mode" and conserves energy.	The circuit board will need revisions after more testing with the prototype units. These changes might also help to decrease the devices power consumption. The immersion switch may need to be moved and/or modified to prevent sea water from forming a droplet on top of it when an animal comes to the surface for brief periods. In these situations the SeaTag-RC would not power up its radio and would think it was still under water. A continuity test circuit needs to be added so that we can remotely test the EPIC trigger resistor circuit board

		before and after the unit is deployed.
Data Transmission (3.4)	After testing various radio modules we selected the 900mhz Digi ZigBee pro XSC. This radio gave us sufficient range in our tests across the ocean and along beaches (2.4 nautical miles). Its limited data rate (9.6kbps) is sufficient for coded trigger signals to be sent more than ten times per second allowing for a power saving burst mode operation.	
Device software (3.5)	A wireless boot loader has been written and programmed onto the prototype devices. The firmware for the prototype device currently turns on when the device is wet and accepts a variety of commands for getting and setting the devices serial number, model number, and triggering the release mechanism. This allowed us to test the immersion switch and release mechanism without needing more advanced power saving software to address spending long periods out of the water.	The power consumption of the device when asleep is currently 240uA and needs to be decreased to close to 1uA which is the lowest power consumption supported by the microcontroller. The software also needs to be modified to support low power consumption in and out of the water during all modes of operation, not just sleep mode. The security of the triggering command also needs to be addressed. We need to make it very difficult for unintentional or malicious triggering of these devices. As-is the device could be triggered by anyone that knows the trigger command and issues a broadcast get serial number command to know where to send the trigger command.
Manufacturing	The carrier platform housing and electronics board have successfully been manufactured. Two units were potted with electronics in their housings to be used as test units. Manufacturing of the final product, after modifications, will begin during phase-2.	There were a few bubbles in the epoxy of each of our prototype units even after putting them in a vacuumed chamber. They weren't in critical spots but this needs to be solved for the production units.

RESULTS

The most important thing that was learned from this project was how to build a small energetic release mechanism. This is a key technology block for the development of a variety of instrumentation. Although the tag itself will take some time to commercialize due to the scheduling of other tags before it, the release mechanism will be deployed much sooner on another tag. Other things learned involved material selection for use around the burn chamber to prevent shattering.

IMPACT/APPLICATIONS

The release mechanism developed for this device will be useful as a smaller alternative to our acoustic release mechanism. It can be used for a variety of oceanographic instrumentation besides animal tags where the large capacitors needed for our other release mechanism are unacceptable.

RELATED PROJECTS

Products related to the RC can be found at our animal tag page here: http://www.desertstar.com/Products_category.aspx?intProductCategoryID=22. The closest tag is the MOD which uses the same release mechanism developed under this contract.